Quadrupedal Locomotion

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and Joaquin Estremera

Quadrupedal Locomotion

An Introduction to the Control of Four-legged Robots

With 135 Figures

Springer

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To Pili, Jose Pablo and Javier; they form my personal stable tripod.
Pablo Gonzalez de Santos

To Luis Angel and Irene; you give direction to the walk of my life.
Elena Garcia

To Beatriz, to whom I will run back soon.
Joaquin Estremera

Preface

Legged robots have proven to be a promising locomotion system, capable of performing tasks that conventional vehicles cannot perform. Even more exciting is the fact that this is a rapidly developing field of study for researchers from a variety of disciplines. Over the past three decades, legged locomotion technology has been developed all over the world, resulting in the invention of many important new machines and methods. However, only a few books have been published on the subject of multi-legged robots. The main objective of this book was to explore some of the major issues that the authors have been analyzing over the past ten years. A second objective was to write a book that only encompasses quadruped locomotion, the first specialized book on this topic. The book is divided into two parts: Walking Measurements and Algorithms, and Control Techniques. The first part is devoted exclusively to the theoretical aspects of quadrupeds. The first chapter is an introduction to the historic development of multi-legged robots, highlighting their advantages and disadvantages, main features, and potential and actual applications, as well as discussing basic concepts and the trade-off between quadrupeds and hexapods. Finally, new and traditional stability measurements and gait generation algorithms for quadrupeds are explained. The second part of the book deals with general design and control algorithms (kinematics and dynamics) and techniques aimed at improving the main features of robots, such as speed and ground detection, interfaces, *etc.* These techniques are used for legged robots in general, but this book applies them specifically to quadruped robots. The material presented in the book is the result of a true group effort involving many different individuals. We are especially grateful to the members of the Industrial Automation Institute (CSIC) who provided many valuable contributions to the machining and maintenance of the SILO4 walking robot. We would also like to thank our colleagues at the Department of Automatic Control, who provided direct assistance with the experimental work. We are deeply indebted to the department head, Dr. M. Armada, for his unconditional support. We would like to express our gratitude for the contributions of Dr. M.A. Jimenez. She could have been one of the authors of this book,

but instead she decided to follow her husband on another exciting adventure in The Netherlands. The support of Dr. J.A. Galvez, who created the main mechanical design of the SILO4 walking robot, is also greatly appreciated. Finally, we would like to acknowledge the financial support of the Spanish Minister of Education and Science. Most of the results contained in the book were funded by grants from this institution (ROB1990-1044-C02-01, TAP94-0783, TAP1999-1080-C04-01, DPI2001-1595 and DPI2004-05824). The second author also gratefully acknowledges funding from the European Social Fund for her CSIC-I3P contract.

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